

From Analyzing Geotechnical Failures to Generating and Solving Crossword Puzzles: Adding Variety to a Geotechnical Engineering Course

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Abstract

The civil engineering majors at our institution take the first geotechnical engineering course in their senior year. At that time, they have already been introduced to all sub-disciplines of civil engineering, except geotechnical engineering. As an instructor, it then becomes a challenge to introduce students to an unfamiliar sub-discipline, since by all likelihood; they have already decided on the field they will pursue in employment or graduate study. An effective strategy for addressing this issue is to design the course to provide various active teaching and learning strategies that engage students and focus on their different learning styles. This paper discusses how various active teaching and learning techniques focused on different learning styles were employed in a geotechnical engineering course. The paper also reports effectiveness of these techniques on student learning gains and students' self-perception of the active learning tools.

Keywords

Instructional pedagogy, Geotechnical Engineering

Introduction

As a requirement for graduation, civil engineering majors at The Citadel, a teaching-focused college in the Southeastern United States, must take two geotechnical engineering courses in their senior year. The first course focuses on basic principles of soil mechanics and the second course focuses on the analysis and design of foundations. The first geotechnical engineering course is offered in the fall semester in both the day and evening programs. Day classes are taken primarily by members of the Corps of Cadets, meeting three times week. A relatively small percentage of the classes are occupied by active duty or veteran students, who take day classes with the Corps of Cadets. Evening classes meet twice a week and are populated with students who live in the community, many of whom work full or part-time. Veterans that have been approved for day status may also attend evening classes in the fall and spring. At this juncture, students have already been exposed to all civil engineering sub-disciplines, except geotechnical engineering. As an instructor, it then becomes a challenge to introduce students to an unfamiliar sub-discipline, since by all likelihood; they have already decided on the field they will pursue in employment or graduate studies. An effective strategy for addressing this issue and such a diverse group of students, who have such different learning styles, different working and academic experiences, is to design a course to provide a variety of active teaching and learning strategies that engage students and focus on their different learning styles.

As stated in the literature, to maximize student learning, it is essential to incorporate teaching and learning methods that adequately address the different learning styles, and develop ways to

promote student motivation and engagement^{1,2}. Motivation to learn affects the amount of time students are willing to devote to learning. Bransford et al.³ reports that students are more motivated when they can see the usefulness of what they are learning and when they can use it to do something that has an impact on others. Furthermore, Bransford et al.³ states that the likelihood that knowledge and skills acquired in one course will transfer to real work settings is a function of the similarity of the two environments. Various active teaching and learning tools employed to enhance the first geotechnical engineering course and the direct and indirect assessments of their effectiveness are discussed herein.

Active Teaching and Learning Techniques Used

As a first in-class activity on the first day of class, students were asked how the geotechnical engineering course relates to others they had taken and its significance in a broader picture. As a second activity, students were provided with the results of subsurface investigations and several soil samples from a site on-campus. They were asked to draw a Concept Map⁴ of information they would need to design a foundation system for a building. It is important to note that this real world problem was used in subsequent lessons to introduce each new geotechnical concept and to provide context for the analysis and design of a foundation system. Using this real world problem also provided a stimulus for learning, created student motivation and excitement for learning and promoted deep learning. As a last activity, prior geotechnical knowledge of the students was assessed by administering a 10-question, short-answer pre-test which was based on the learning objectives of the course. Both Concept Maps and the short answer pre-test revealed valuable information about misconceptions students brought to the course.

Prior to each lesson, web-based pre-class reading responses⁵ were employed to motivate students to prepare for class regularly. Students were required to respond to one or two open-ended question on the course website addressing the learning objectives of a specific lesson. Immediately before class, student responses were examined and the in-class activities were tailored to meet their actual needs. The following is an example from one of the pre-class reading responses: Students were asked to explain how they would manipulate two samples of sand to achieve void ratios of 0.75 (relatively high void ratio) and 0.4 (relatively low void ratio). To further stimulate learning and to get the students motivated about geotechnical engineering, a song with the word soils or rock (i.e., “Enter Sandman” by Metallica; “We Built this City on Rock and Roll” by Starship; “I am a Rock” by Simon and Garfunkel, etc.) was played prior to each lesson. Learning objectives were written on the board and were referred to frequently during class to assist both sequential and global learners as to where the content fit into the knowledge they were assembling². In addition, as students entered the classroom, thought provoking questions were written on the board, and they were instructed to write their responses to the questions on a sheet of paper. Students were then asked to pick one question to discuss and correct any misconceptions as a group and report the summary to the entire class.

At the beginning of each lesson, pre-class reading responses were summarized on the board and common errors were discussed. Following the discussion, Think-Pair-Share technique, a form of peer learning⁶, was employed to help the reflective and active learners organize prior knowledge and engage with the geotechnical concepts. First, students were required to formulate their own ideas and share it with a peer. Next, a list of all class ideas was written on the board and through

discussion, students decided on the best answers to the posed question. This strategy also makes it virtually impossible for students to avoid participation, thus making each student accountable⁷.

Students were provided with daily handouts, which contained a partially completed outline of the lesson and a number of questions, with blank spaces for answers. A mini-lecture was employed to correct the misconceptions and allow the students to fill-in-the-blanks in their handouts. Furthermore, the mini-lecture was used to assist the verbal learners with explanations and derivations of formulas and the sequential learners with the logical flow of geotechnical topics. For the global learners, the presented material was always linked to students' previous knowledge and previous concepts in soil mechanics and to future material in analysis and design of foundations. For example, when discussing the concept of effective stress, it was linked to both the previous knowledge (i.e., the Archimedes' principles, and the inter-relationships of weights and volume) and the future materials in geotechnical engineering (i.e., the compressibility of soil, bearing capacity of foundation and lateral earth pressure on earth retaining structures).

To address the visual learners, physical models were developed and used to demonstrate the key geotechnical concepts such as: particle size ranges, shape of the grain size distribution curve, hydraulic conductivity of soil, effective stress, consolidation and shear strength. On occasion, video clips of geotechnical failures were used to provide students with real world examples of geotechnical engineering practice.

Frequently, hands-on small group problem solving was used to assist the active and sensing learners with the geotechnical engineering concepts. Once a week, individual and team quizzes were administered on the assigned readings. This technique was effective at motivating students to come to class prepared. On occasion, clickers were employed to assess the understanding of geotechnical concepts and create an environment to engage students and provide immediate feedback to both students and instructor. Students worked problems with peers and each team submitted responses using a clicker.

At the end of each lesson, One-Minute paper⁸ and Muddiest point paper⁹ activities were used to monitor student learning. One-Minute paper technique required students to answer a big picture question from the material that was presented in the current or previous lesson in 60 seconds. Muddiest point paper required students to write the single, most confusing point related to the concept on a piece of paper. After class, the muddiest points were addressed and posted to the course website. These two techniques not only assisted the reflective learners, but also addressed student's misconceptions and preconceptions.

According to Moore and Dettlaff¹⁰, the use of games in the classroom can also be an effective tool to address the diverse learning styles. Moore and Dettlaff also state that games can add flexibility to the classroom and allow students to adjust to the way in which they learn best. Another positive outcome of using games in the classroom is that participation in them makes learning a matter of direct experience¹¹. Another study¹² reports a number of benefits to using games in the classroom, including teaching student alternative techniques to studying, impacting cognitive development, motivating students to learn instead of simply memorizing, and boosting student's confidence when they get a correct response. For these reasons, crossword puzzles, Jeopardy-style questions and Pictionary were employed as review tools for the midterm exams.

On the last day of class, students were asked to compile a list of concepts or words that cover geotechnical engineering's main ideas. The class was split into two groups and students were given five minutes to write down words that capture any concept that had been covered in the course. Next, the 10 best words were selected and each was written on its own index card. When playing the game of Pictionary, students were asked to draw on the board to convey the meaning of words, which benefited the visual learners. Each group had seven minutes to see how many of the other groups' words or phrases they could guess. The group with the lowest combined time was the winner. As a next activity, students were asked to draw a concept map of information that they would need to design a foundation system for the new building on campus. The Concept Map completed on the last day of class showed significant improvement over the one done on the first day of class. Students were now clearly able to organize the concepts and to establish meaningful relationships among geotechnical concepts.

Real world open-ended homework assignments directly linked to the learning objectives were devised to scaffold student understanding of geotechnical concepts. The assigned homework not only stimulated creativity and deep thinking about the material, but also required them to use their engineering judgment. For example, one assignment required students to develop a representative soil profile for the site on campus. To accomplish the task, students conducted laboratory index testing on recovered Standard Penetration Test samples at different depths. In addition, they estimated soil parameters such as: pre-consolidation stress, friction angle, and undrained shear strength from the field data. The developed soil profile was used by students to design a foundation system for the building on campus in the subsequent course.

To further deepen the understanding of the course material, students were required to select a geotechnical failure and conduct an in-depth study of why the failure occurred through the exploration of several sources (e.g., textbook, journal articles, and websites). Students were also required to explain the mechanism (s) of failure using the concepts learned in the course and compose a technical report documenting the findings of the analysis.

Assessing the Effectiveness of Various Techniques

At the end of the course, students' perceptions of various active learning techniques were assessed anonymously by examining their responses on a survey. They were asked how effective the various teaching and learning tools were in helping them to learn the course materials (see Figure 1). They were also asked to rate each teaching and learning technique as very ineffective, not effective, somewhat effective, effective, or very effective. Overall, students' responses reflected a positive perception of the teaching and learning techniques. Students rated real world homework assignments, individual and group quizzes, hands-on problem solving, analyzing geotechnical failures, and games very highly, with more than 85% rating them as effective or very effective as shown in Figure 1. Percentage of students that indicated that the peer instructions, Muddiest point and Minute papers, and physical models were effective or very effective were 63%, 69%, 77%, respectively. Only 33% of students rated the web-based pre-class reading responses as very effective or effective. It is speculated that such a low percentage for web-based responses may be attributed to the fact that students at our institution are not accustomed to doing web-based work, and for many, this may have been the first time having to do so in their college classes.

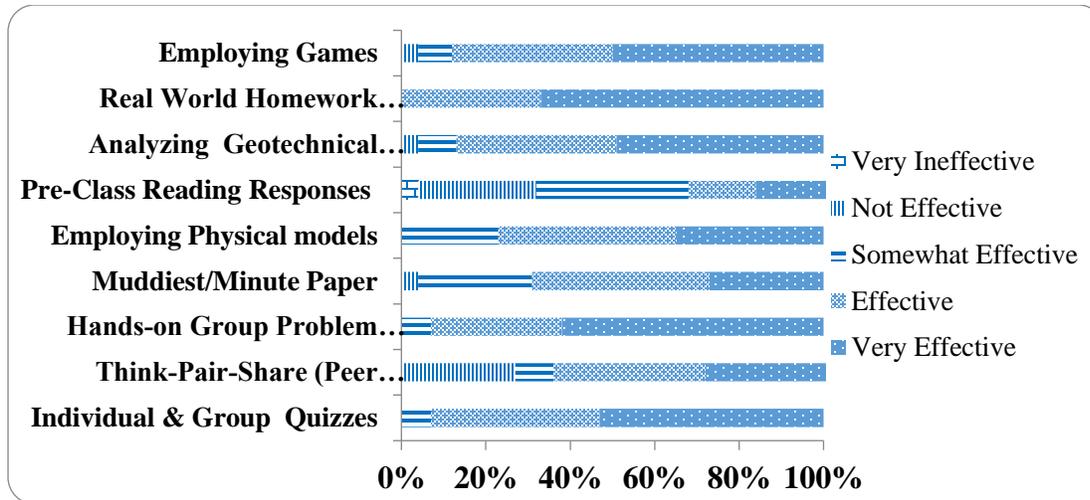


FIG. 1. Student rating of various teaching and learning techniques used

Effectiveness of the various teaching and learning techniques was measured directly by employing a pre- and post-test methodology. A pre-test based upon the course learning objectives was administered on the first day of semester. The same short-answer test was administered on the last day of semester to measure the learning as a result of the course experience. It is important to note that neither the pre-test nor post-test counted toward the course grade.

SPSS software was employed to perform a paired-samples t-test on pre-test and post-test data. The results showed that there was a significant difference in scores for pre-test and post-test. There was an increase from an average score of 12.7% on the pre-test to an average score of 74.6% on the post-test (mean paired diff = 61.9%; $t(51) = 435.64$, $p\text{-value} < 0.001$). The difference between pre- and post-test means was statistically significant ($p < 0.001$), revealing substantial learning gain. Moreover, the differences between means were not likely due to chance and were most likely due to the use of the various teaching and learning techniques. All students had significant gains from pre-test to post-test on the geotechnical concepts. The knowledge gained was influenced more by the amount of time students spent working on the concepts and how they were stimulated by the material rather than by students' geotechnical knowledge prior to the start of the course.

Conclusions

A variety of teaching and learning tools were employed to introduce the senior civil engineering majors at The Citadel to the sub-discipline of geotechnical engineering. These techniques, not only engaged and motivated students to learn the fundamental geotechnical concepts, but also focused on their learning styles. The effectiveness of these techniques was assessed indirectly by examining student responses on a self-perception survey and directly by measuring student learning through the use of a pre- and post-test instrument. More than 85% of students rated real world homework assignments, individual and group quizzes, hands-on problem solving, analyzing geotechnical failures, and games as effective or very effective. The direct assessment

of the learning objectives also showed statistically significant gains in learning of geotechnical concepts. The learning gains were influenced more by the amount of time students spent working on the concepts and how they were stimulated by the material, rather than by student's geotechnical knowledge prior to the start of the course.

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